0363-5465/103/3131-0981$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 31, No. 6

Clinical, Functional, and Radiologic Outcome in Team Handball Players 6 to 11 Years after Anterior Cruciate Ligament Injury

A Follow-up Study

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Background: Long-term outcome after anterior cruciate ligament injury among top-level pivoting athletes is unknown.
Purpose: To evaluate outcome among competitive team handball players after anterior cruciate ligament injury.
Study Design: Prospective cohort study.
Methods: A previously studied group of 86 elite players who had an anterior cruciate ligament rupture were invited to participate in follow-up evaluations a mean of 7.8 years later.
Results: Among the 57 operatively treated patients who returned for follow-up, 33 (58%) returned to team handball at their preinjury level, compared with 18 of 22 (82%) in the nonoperative group. Eleven of the 50 players (22%) who continued playing reinjured their anterior cruciate ligament when playing team handball. The overall Lysholm score was 85 ± 13 in both groups, but the five players classified as poor were all operatively treated. Nearly half of the players had an International Knee Documentation Committee classification of abnormal or severely abnormal. There were significant differences between the injured and uninjured leg in functional (2.5% to 8%), strength (3.8% to 10.1%), and KT-1000 arthrometer tests (27%). In the operatively treated group, 11 developed radiologic gonarthrosis, compared with 6 in the nonoperatively treated group. There was no correlation between radiologic findings and pain scores.
Conclusion: A more restrictive attitude regarding return to competitive pivoting sports after anterior cruciate ligament injury may be warranted.

A high incidence of ACL injuries has been reported among players of team handball, as well as in players of other team sports, such as basketball, volleyball, and soccer.[8,9,15,18,19,24,25,43] The treatment of ACL injuries has improved during the last 10 to 15 years, such that many patients are able to return to high-level sports participation. It seems generally accepted that the preferred treatment for injured athletes in pivoting and high-speed sports is a delayed reconstruction of the ACL with use of a patellar or hamstring tendon graft.[21]

Although advances in surgical technique have been made, exact information on the return rate of athletes to preinjury sporting level after an ACL injury is limited. Daniel et al.[6] demonstrated, in a prospective outcome study, that almost half of their patients, whether operatively or nonoperatively treated, continued with sports such as basketball, soccer, racket sports, or skiing. Roos et al.[35] examined soccer players, representing all levels of competition, 3 and 7 years after ACL injury. They found that only 30% of the players were active in soccer 3 years

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No author or related institution has received any financial benefit from research in this study. See "Acknowledgements" for funding information.

after injury, compared with 80% in an uninjured control population. After 7 years, none of the injured elite players were active at the same level, independent of whether they were treated operatively or nonoperatively after the injury.[35] Strand and Solheim (unpublished data, 1999) showed that only a third of team handball and soccer players had returned to their preinjury level 2 years after their ACL reconstruction. Scavenius et al.,[37] in a study of nonoperatively treated patients 7 years after ACL injury, found that only 2 of the 24 players returned to performing cutting sports. However, the available studies have examined mixed groups of patients from different sports and mainly those who participated at lower performance levels. No data are available on the return rate after an ACL injury among elite athletes in a pivoting sport such as team handball.

Moreover, few studies have reported on the reinjury risk after ACL reconstruction. Mitsou and Vallianatos[23] reported only one graft rupture in a 5- to 9-year follow-up study of 334 athletes after reconstruction with use of the lateral third of the patellar tendon, but the sports activities of the patients after reconstruction were not reported. Sandberg and Balkfors[36] conducted a 5-year follow-up of 112 patients treated with a reconstruction of the ACL with the middle third of the patellar tendon, and they found that 11 (10%) reconstructions had ruptured, 8 of them during sports activity. Otto et al.,[31] in a 5-year follow-up of patients with patellar tendon autograft ACL reconstructions, found that only 3 of 80 (4%) patients had a rerupture of their ACL, 2 of them in pivoting sports. Bak et al.[3] studied 132 soccer players who had had reconstruction with an iliotibial band graft and found a higher rerupture rate among female players than among male players. Three of 15 female players (20%), compared with only 1 of 117 men (0.3%), had a rerupture of their reconstructed ligament. However, all of these studies were based on mixed patient populations of nonathletes and athletes from different sports and performance levels. The rerupture rate among elite athletes in knee-demanding sports is unknown.

One potential long-term problem after an ACL injury, whether the treatment is operative or nonoperative, is osteoarthritis of the knee. In a review article, Gillquist and Messner[11] concluded that the prevalence of radiographic gonarthrosis is increased after all types of knee injuries compared with the uninjured joint of the same patient. A total rupture of the ACL seems to increase the risk 10-fold compared with an age-matched uninjured population. This serious consequence occurs despite surgical correction of the instability. We still lack evidence to suggest that ACL reconstruction decreases the rate of posttraumatic osteoarthritis in the knee. In fact, it may even be hypothesized that an effective ACL reconstruction increases the risk of future osteoarthritis by enabling the athlete to return to high-performance pivoting sports—either through reinjury or because of the high demands put on the knee.

In other words, so far there are no studies on a homogeneous group of competitive pivoting-sport athletes examining the short-term (return to sport) or long-term (knee function, radiographic evidence of osteoarthritis, and participation in sport and activities of daily living) consequences after an ACL injury.

Thus, the aims of this study were to evaluate the return rate to sport at preinjury level, the reinjury rate after reconstruction, and clinical outcome 6 to 11 years after an ACL injury in a cohort of competitive team handball players. We also wanted to examine the prevalence of radiologic changes and their relationship to clinical outcome.

MATERIALS AND METHODS

In the present study, we made use of the patient population of a previous study in which all 87 ACL injuries of players in the three upper divisions of Norwegian team handball were recorded prospectively during the 1989 to 1990 and 1990 to 1991 seasons.[24] One of the original 87 patients was later found to have a PCL injury. The remaining 86 patients (53 women and 33 men) were invited to take part in the present study, and 79 (91%) responded to a questionnaire 7.1 years (range, 6 to 8) after their injury. Four patients were not available for follow-up because they had emigrated, and three patients declined to take part in the study. The Data Inspectorate and the Regional Ethical Committee for Medical Research approved the study, and the players gave their written consent to participate after receiving information about the purpose and procedures of the study.

In addition to answering the questionnaire, the athletes were asked to participate in a clinical examination, International Knee Documentation Committee (IKDC) evaluation, Lysholm scoring, functional tests, KT-1000 arthrometer (Medmetric Corp., San Diego, California) examination, strength tests, and a radiologic examination. Their hospital records were also obtained to confirm the original diagnosis and to classify the type of operation when surgical reconstruction had been performed. The initial diagnosis was confirmed arthroscopically in 64 cases and by clinical examination in 15. None of the current authors had performed the original surgical procedures.

Seventy-one players (46 women and 25 men) had a clinical examination and KT-1000 arthrometer testing, 70 had an IKDC evaluation, 69 had functional tests and Lysholm scoring, 63 had a strength test, and 50 had a radiologic examination an average of 9.4 years (range, 7 to 11) after injury.

Questionnaire

The players were interviewed in person or by telephone and answered a standardized questionnaire regarding personal data, rehabilitation and recovery history, return to sport, history of knee problems after the ACL injury, and any consequences the injury may have had for performance of their activities of daily living.

Clinical Examination

A clinical examination of both knees was performed by two experienced physicians. Range of motion was measured

with a goniometer, and thigh circumference was measured 5 and 10 cm from the top of the patella. Patellofemoral pain and crepitation were graded as 0 (absent), 1+ (mild), 2+ (moderate), or 3+ (severe). Lachman, anterior drawer, pivot shift, and medial and lateral joint opening (at 0° and 30° of flexion) tests were performed. Anterior laxity was graded as 1+ (0 to 5 mm), 2+ (6 to 10 mm), or 3+ (>10 mm).

KT-1000 Arthrometer Testing

The KT-1000 arthrometer examination (MEDmetric, San Diego, California) was performed by the same experienced physical therapist, who used the 134-N and manual maximal tests described by Daniel et al.[7] A side-to-side difference of 3 mm or more was defined as abnormal.

Muscle Performance Test

Isokinetic equipment (Cybex 6000 dynamometer, Cybex-Lumex, Inc., Ronkonkoma, New York, or Biodex System 2 Isokinetic Dynamometer, Biodex Medical Inc., Shirley, New York) was used to evaluate quadriceps and hamstring muscle performance. All of the tests were performed by the same experienced physical therapist. Before testing, the players warmed up on a cycle ergometer for 8 minutes. They were then fixed to the apparatus with straps securing the chest, pelvis, thigh, and ankle.[16] Both limbs were tested, the uninvolved side first. The protocol consisted of five repetitions at an angular velocity of 60 deg/sec followed by a 1-minute rest period and 30 repetitions of 240 deg/sec. The results were reported as the mean value of total work at both angular velocities.

Functional Testing

The players performed a single-jump test, a triple-jump test, and the stairs hopple test.[34] The single-jump test was performed with the player jumping and landing on the same leg, uninvolved side first. The triple-jump test was performed with the player first standing on the uninjured leg, jumping twice on the same leg, and landing on both legs. The same procedure was used for the involved leg. Two trials were performed on each leg, and the best performance was recorded. In the stairs hopple test the players were timed while jumping up and down 22 steps (each step 17.5 cm high), first on the uninvolved side, subsequently on the involved side, with one trial for each leg.

IKDC and Lysholm Evaluation Forms

The IKDC[13] and Lysholm[20] rating scales were used by the physician in the course of the patient examination to evaluate knee function. The IKDC evaluation form consists of eight variables: patient subjective assessment (IKDC 1), symptoms (IKDC 2), range of motion (IKDC 3), ligament examination (IKDC 4), compartmental findings (patellofemoral crepitus), harvest site pathologic findings, radiographic findings, and the single-legged hop test. Only the first four variables (IKDC 1 to 4) are graded, as normal (1), nearly normal (2), abnormal (3), or severely abnormal (4). The worst subgroup evaluation determines the group qualification, and the worst group qualification determines the final evaluation. In this study, the IKDC 1 to 4 and the IKDC final scores were evaluated. Data on compartmental findings were not collected. Results from the radiographic evaluation, harvest site pathologic findings, and functional tests are not included in the IKDC final score and have been reported separately.

The Lysholm score consists of eight items, and instability and pain account for 25 points each of the total score of 100 points. In this scale, 95 to 100 points is considered excellent, 84 to 94 good, 65 to 83 fair, and 64 and below is considered poor.[20]

Radiographic Assessment

An experienced orthopaedic surgeon, blinded to the clinical outcome, assessed the standing frontal radiographs. Gonarthrosis was defined as joint space narrowing with a loss of distance between the tibia and the femur in one compartment of half or more of the distance in the other compartment of the same knee joint, or the same compartment of the other knee, or less than 3 mm.[1]

Statistical Methods

The descriptive data are presented as the arithmetic mean, standard deviation, or range, or both, unless otherwise noted. Paired *t*-tests were used to compare the involved and uninvolved legs. Unpaired *t*-tests were used to compare group means. For nominal categorical data, a chi-square test was used to determine whether there were significant differences between groups. A Mann-Whitney test was used for ordinal categorical data. One-way analysis of variance was used to test mean differences between different treatments. An alpha level of 0.05 was considered statistically significant.

RESULTS

Treatment

Of the 79 players (50 female and 29 male) interviewed, 57 (72%; 37 women and 20 men) were treated operatively, and 22 (28%; 13 women and 9 men) were treated without surgery. From the hospital records, we found that 47 players (82%) in the operative group had a bone-patellar tendon-bone graft reconstruction, in 8 cases (14%) the ligament was sutured, and the procedure performed on 2 players (4%) was unknown. The players in the operative groups had gone through 1.7 surgical procedures (range, 1 to 8) from the time of injury to the follow-up examination.

Return to Sport

In the nonoperatively treated group, 18 players (82%; 11 women and 7 men) returned to team handball at the same level they played before the injury occurred. Two players continued playing on a lower level, and two players never

played team handball after their injury. In the operatively treated group, 33 players (58%; 20 women and 13 men) continued playing at the same level, 17 (30%) played at a lower level, and 7 never played again. The players in the nonoperative group continued playing at the same level for 4.1 years (range, 1 to 10), compared with 3.8 years (range, 1 to 7) in the operative group.

Reinjury Risk

Of the 50 players in the operative group who continued playing team handball, 11 (22%) reinjured their ACL, all when playing team handball (Fig. 1). Of the 11 patients with reinjuries, 5 underwent reconstructions with bone-patellar tendon-bone grafts, 4 had primary repairs, and "other" techniques were used for 2. Eight of the reinjured players underwent a second operation, all of them with a bone-patellar tendon-bone graft procedure. Two of them reruptured their ACL a second time while playing team handball. Six of the players (9%) who continued playing team handball ruptured the ACL of their previously uninjured knee. There were no reinjuries among the seven players who had undergone a bone-patellar tendon-bone graft and had subsequently quit playing team handball.

Types of Problems

The main problems in the nonoperative group were instability (60%) and joint effusion (23%), whereas the operative group reported problems with reduced range of motion (44%), instability (26%), reduced muscle strength (25%), and joint effusion (23%). Knee problems had forced 12 patients (55%) in the nonoperative group and 26 (46%) in the operative group to reduce or stop leisure and sports activities. Five patients (23%) in the nonoperative group and 15 (26%) in the operative group reported work-related problems caused by their knee condition. Twenty-nine (51%) of the players in the operative group reported patellofemoral pain, and 16 (28%) of them had tenderness to palpation of the distal patellar pole. In the nonoperative group, three patients reported patellofemoral pain (14%).

Lysholm Score

The Lysholm score was 85 ± 13 (N = 69). On the basis of their Lysholm score, 19 patients (28%) were classified as excellent, 30 as good (43%), 15 as fair (22%), and 5 as poor (7%). The five patients who were classified as poor were all in the operative group, four had had a bone-patellar tendon-bone graft procedure, and the ACL of one had been sutured. Figure 2 shows Lysholm scores for women and men in the different treatment groups. There was no difference between the three treatment groups (P = 0.3).

IKDC Evaluation Score

From their scores on the IKDC evaluation system (N = 70), 9 patients (13%) were classified as normal, 31 (44%) as nearly normal, 21 (30%) as abnormal, and 9 (13%) as severely abnormal (Fig. 3). The nine players classified as severely abnormal were all in the reconstructed group. Five of them received their abnormal score from IKDC 1 (patient's subjective assessment) and four from the IKDC 2 (symptoms).

Functional Tests

Performance was reduced in the involved compared with the uninvolved side for the single-legged jump (P = 0.006), triple-jump (P = 0.003), and stairs hopple tests (P = 0.018) (Table 1). There was no difference between the treatment groups in the triple-jump test (P = 0.92), single-legged jump test (P = 0.57), or stairs hopple test (P = 0.66).

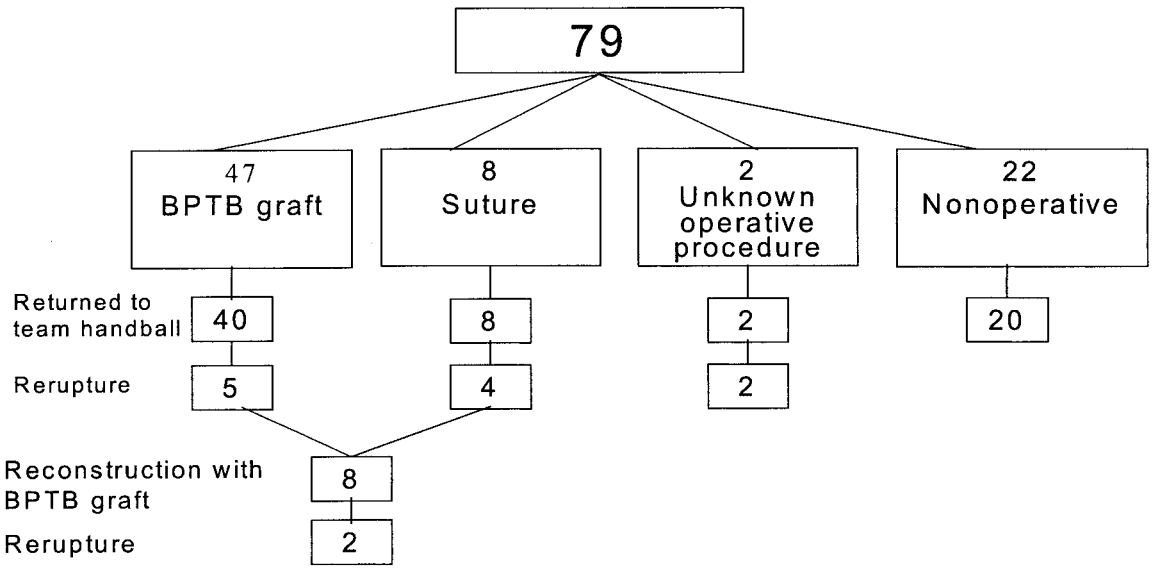

Figure 1. Flowchart depicting treatment history, return to sport, and the number of reruptures. BPTB, bone-patellar tendon-bone.

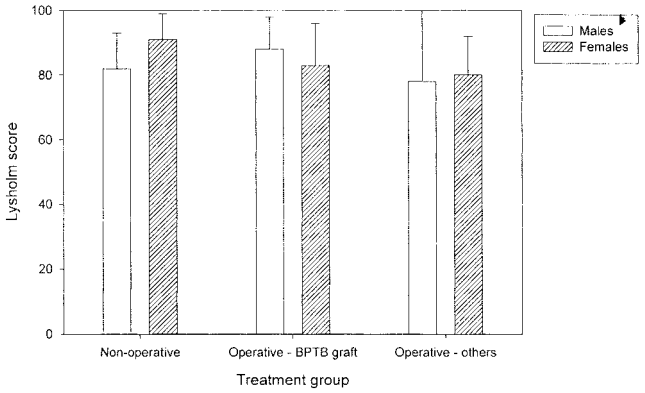

Figure 2. Lysholm score ± standard deviation for both sexes and for the three treatment groups: patients treated nonoperatively, with a bone-patellar tendon-bone (BPTB) graft, or with other operative procedures.

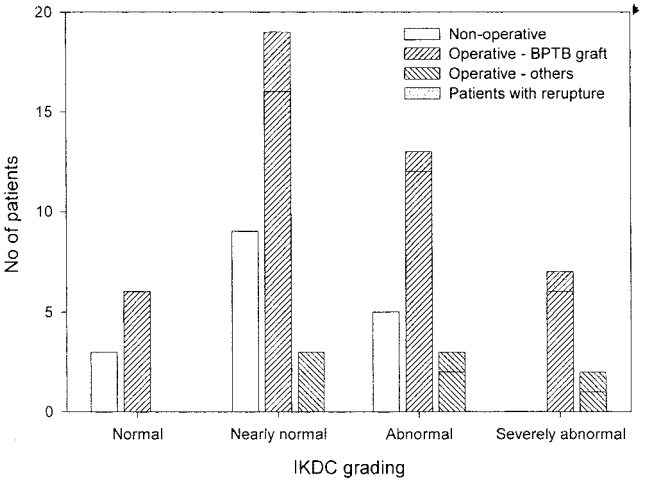

Figure 3. Overall IKDC assessment results ($N = 70$) for the three treatment groups: patients treated nonoperatively, with a bone-patellar tendon-bone (BPTB) graft, or with other operative procedures. Patients with reruptures in each group are shown with shaded bars.

Muscle Strength Tests

Performance was reduced in the involved compared with the uninvolved side for total work during flexion at 60 deg/sec ($P = 0.038$), flexion at 240 deg/sec ($P = 0.03$), extension at 60 deg/sec ($P = 0.000$), and extension at 240 deg/sec ($P = 0.000$) (Table 2). There was no difference in the involved-uninvolved leg difference for total work during flexion at 60 deg/sec ($P = 0.15$), flexion at 240 deg/sec ($P = 0.30$), extension at 60 deg/sec ($P = 0.94$), or extension at 240 deg/sec ($P = 0.46$) between the treatment groups.

Knee Stability (KT-1000 Arthrometer Testing)

All treatment groups showed an increased anterior displacement when the involved was compared with the uninvolved leg (Table 3). In the group treated with a bone-patellar tendon-bone graft procedure, 17 of 42 patients (40%) showed a side-to-side difference of less than 3 mm in anterior displacement, 15 patients (36%) displayed a difference of 3 to 5 mm, and 10 patients (24%) showed more than a 5-mm difference. Among the patients treated with other procedures and among nonoperatively treated patients, the corresponding figures were seven (<3 mm, 58%), one (3 to 5 mm, 8%), four (>5 mm, 33%), and seven (<3 mm, 41%) for the operatively treated group and two (3 to 5 mm, 12%) and eight (>5 mm, 47%) for the nonoperatively treated group. There were no differences in the 30-pound test ($P = 0.20$) or manual maximal test ($P = 0.44$) between the different treatment groups.

Thigh Circumference

Among the operatively treated patients, 36 (63%) had full quadriceps muscle bulk or less than 1 cm difference between the two limbs, 16 (28%) had a 1- to 2-cm difference, 4 (7%) had a 2- to 3-cm difference, and 1, more than a 3-cm difference. In the nonoperatively treated group, 20 players (91%) had less than 1-cm thigh difference, and 2 players (9%) had a 1- to 2-cm difference.

Radiologic Findings

Radiographs were obtained of the knees of 13 players from the nonoperatively treated group and 37 players from the

TABLE 1
Test Result Differences between the Involved and Uninvolved Leg for the Whole Group and for the Three Treatment Groups[a]

Test	All patients			Differences by treatment group		
	Uninvolved	Involved	Difference	Nonoperative	BPTB[b] graft	Other operative
Triple jump (cm)	527 ± 10[c] ($N = 69$)	514 ± 10 ($N = 69$)	13 ± 4.3 (2.5%)	11 ± 8 (2.2%) ($N = 17$)	15 ± 5[d] (2.4%) ($N = 41$)	10 ± 13 (2.2%) ($N = 11$)
Single-legged jump (cm)	156 ± 3.3[c] ($N = 68$)	150 ± 3.6 ($N = 68$)	6 ± 1.9 (8%)	2 ± 3 (0.7%) ($N = 17$)	7 ± 3[d] (4.4%) ($N = 41$)	7 ± 7 (3.3%) ($N = 10$)
Stairs hopple test (sec)	29 ± 1.2[d] ($N = 58$)	31 ± 1.4 ($N = 58$)	2 ± 0.8 (6.9%)	2 ± 1 (2.9%) ($N = 17$)	1 ± 1 (3.6%) ($N = 32$)	3 ± 2 (12.5%) ($N = 9$)

[a] Results are shown as mean or mean side-to-side differences ± standard error.
[b] Bone-patellar tendon-bone.
[c] Significant difference between the involved and the uninvolved leg ($P < 0.01$).
[d] Significant difference between the involved and the uninvolved leg ($P < 0.05$).

TABLE 2
Total Work Differences (in Joules) between the Involved and Uninvolved Leg for the Whole Group and the Three Treatment Groups[a]

Test	All patients (N = 63)			Differences by treatment group		
	Uninvolved	Involved	Difference	Nonoperative (N = 15)	BPTB[b] graft (N = 37)	Other operative (N = 11)
Flexion total work						
60 deg/sec	572 ± 19[c]	550 ± 18	22 ± 10 (3.8%)	34 ± 22 (6.0%)	7 ± 13 (1.0%)	59 ± 29 (10.2%)
240 deg/sec	1520 ± 64[d]	1376 ± 59	144 ± 31 (9.5%)	221 ± 71[e] (14%)	134 ± 40[e] (8.6%)	73 ± 60 (5.4%)
Extension total work						
60 deg/sec	900 ± 28[d]	809 ± 26	91 ± 18 (10.1%)	80 ± 19[d] (8.8%)	93 ± 24[d] (11.1%)	99 ± 64 (10.2%)
240 deg/sec	2286 ± 87[d]	2061 ± 77	225 ± 40	137 ± 83 (6.1%)	257 ± 46[d] (11.1%)	238 ± 125 (10.2%)

[a] Results are shown as mean or mean side-to-side differences ± standard error.
[b] Bone-patellar tendon-bone.
[c] Significant difference between involved and uninvolved leg ($P < 0.05$).
[d] Significant difference between involved and uninvolved leg ($P < 0.001$).
[e] Significant difference between involved and uninvolved leg ($P < 0.01$).

TABLE 3
Anterior Displacement Results (in Millimeters) between the Involved and the Uninvolved Leg for the Whole Group and the Three Treatment Groups[a]

Test	All patients (N = 71)			Differences by treatment group		
	Uninvolved	Involved	Difference	Nonoperative (N = 17)	BPTB[b] graft (N = 42)	Other operative (N = 12)
30 pounds	9.6 ± 0.4[c]	13.2 ± 0.4	3.6 ± 0.4 (27%)	4.9 ± 0.9[c] (35%)	3.3 ± 0.4[c] (26%)	3.1 ± 1.4[d] (22%)
Manual maximal	10.4 ± 0.3[c]	14.2 ± 0.4	3.9 ± 0.4 (27%)	4.7 ± 0.5[c] (31%)	3.6 ± 0.4[c] (26%)	3.7 ± 1.3[d] (26%)

[a] Results are shown as mean or mean side-to-side differences ± standard error.
[b] Bone-patellar tendon-bone.
[c] Significant difference between involved and uninvolved leg ($P < 0.001$).
[d] Significant difference between involved and uninvolved leg ($P < 0.05$).

TABLE 4
IKDC Pain Score Results Related to Radiologic Findings

Arthrosis	N[a]	Normal	Nearly normal	Abnormal	Severely abnormal
Yes	15	9 (60%)	2 (13%)	1 (7%)	3 (20%)
No	29	21 (72%)	5 (17%)	2 (7%)	1 (4%)

[a] Number of patients with both radiographs and IKDC scores.

operatively treated group. In the nonoperatively treated group, 6 of the 13 players (46%) had developed gonarthrosis, and the corresponding number for the reconstructed group was 11 of 37 (42%). The Lysholm pain score was 18 ± 2 (N = 16) among players with radiologic evidence of gonarthrosis and 19 ± 1 (N = 32) among players without radiologic changes (P = 0.79). There was no correlation between the radiologic findings and the IKDC pain score (P = 0.27) (Table 4).

DISCUSSION

The principal findings of this study population were that the rate of return to sport at preinjury levels was high, whether the patient was treated operatively (58%) or not (82%), but the reinjury rate in the operatively treated group was also high (22%). About half of the players in both groups reported pain, instability, or reduced range of motion 6 to 11 years after their ACL injury. Nearly half of the players had signs of osteoarthritis, although there was no relationship between radiologic status and pain scores.

A follow-up study such as this has some limitations that must be borne in mind when the results are interpreted. The two groups in this study, operatively and nonoperatively treated patients, are difficult to compare because the reasons they were treated as they were are unknown. A selection bias could exist; for example, the knees of patients who underwent reconstruction knee may have been more unstable, and therefore surgery was selected. The nonoperatively treated patients may have chosen nonoperative treatment in consultation with their physicians because they had a functionally stable knee, because they wanted to return to team handball at the same level more quickly, or because they had a strong motivation to rehabilitate without surgery. They may also have been more willing to tolerate giving-way episodes to achieve their goal. All of these are factors that suggest that the operatively and nonoperatively treated groups should be compared only with caution. Also, there may have been similar differences between the patients who returned to elite sport and those who did not. Thus, the primary purpose of the study was not to compare nonoperative with operative treatment or return to sport with retirement from sport, but simply to describe the long-term

results in each of these subgroups. It should be noted that it is not possible to conduct a prospective study where patients are randomized to elite level sport and retirement, or even surgery and nonoperative treatment. Therefore, the only way to examine the long-term consequences of return to top-level pivoting sports is a follow-up study such as this one.

The strength of the present study was that the injured players were followed from the time of injury to the follow-up with a low drop-out rate. To our knowledge, this is the first prospective long-term follow-up study reported on a homogeneous group of high-level athletes from a pivoting sport.

Return Rate to Sport

Previous studies have reported a low return rate to cutting sports after nonoperative treatment for ACL injury.[8,10,26,37] Bjordal et al.[4] concluded that reconstructive surgery was necessary for an athlete to be able to play soccer again. This conclusion is challenged by the findings from our population; 82% of the nonoperatively treated patients returned to competitive team handball at their preinjury level of performance. The reason for this apparent inconsistency may be that the nonoperatively treated group was a selected subgroup of patients with functionally stable knees, but it should be noted that the patients who returned to sports without surgery comprise as much as one-fourth of the entire cohort of injured players. Roos et al.,[35] in a study of ACL-injured soccer players, reported that only 30% of 219 players were still active soccer players after 7 years, and the ability to return to soccer was the same regardless of treatment choice. One explanation for the high rate of return to play in our cohort may have been high motivation and a strong wish to play team handball again, despite the fact that many players had problems with pain, instability, or reduced range of motion.

Reinjury Risk

The high reinjury rate in our study (11 of 50 players who returned to team handball, 22%) is surprising compared with the findings of other studies.[3,23,31,36] One reason for the high rerupture risk could be the fact that many of the players returned to team handball, which in itself is a high-risk sport.[24,25] This is reflected by the fact that 6 of the 50 players who returned to team handball (9%) experienced an ACL tear in their uninvolved and previously uninjured knee during the study period. In another study in which the number of reruptures was reported, Sandberg and Balkfors[36] observed the highest rate among patients whose knees were reconstructed with use of the middle third of the patellar tendon, with a 10% rate (11 of 112).

The choice of reconstructive technique seems to be correlated with the risk of rerupture. It is not surprising that four of the eight knees in which a simple suture technique was used failed. Previous studies have shown that suture of the ACL has a greater failure rate than does bone-patellar tendon-bone autograft.[12,41] Nevertheless, it should be noted that 5 of 40 patellar tendon grafts (13%) also failed, and there were 2 reruptures among the 8 players who underwent a second surgical procedure. It may be argued that surgery was performed in several hospitals by many different surgeons, and that the results may be a reflection of variable surgical skills. For instance, although we were unable to evaluate tunnel placement, it is possible that a fair number of patients may have had improperly placed femoral or tibial tunnels based on the techniques used then. On the other hand, the results reflect the outcome of ACL reconstruction when employed on a large scale.

Moreover, not only the surgical technique chosen, but also the quality of the postoperative rehabilitation programs may have influenced the failure rate. We did not examine the rehabilitation protocols of the players, but because 6 months of rehabilitation supervised by a physical therapist is provided at no cost in Norway, most of them probably followed a training program. During the late 1980s and early 1990s the rehabilitation programs included early full extension after surgery and mainly consisted of strength-based exercises with a combination of closed and open kinetic chain exercises. Recent data suggest that neuromuscular training may prevent ACL injuries,[5] and it may be that strength-based rehabilitation programs alone are inadequate to protect against reinjury.[14,45] Another explanation for the high rerupture risk could be that these players simply represent a high-risk population, characterized by anatomic, hormonal, or other risk factors yet to be identified.[2]

Knee Stability

Many of the players (49%) had anteroposterior (AP) laxity of more than 3 mm, which is defined as pathologic knee instability, and, for the reconstructed group, these results are considered failures according to universal failure definitions.[3] Still, many of them continued to play team handball. In a comparative study of two different techniques for ACL reconstruction, O'Neill[30] found two patients with 7- and 9-mm side-to-side difference in knee laxity, and both participated in sports and had a perfect Lysholm score. One reason for the high proportion of players with instability could be that they had stretched their ACL while continuing to play team handball, although they may have been initially stable or stabilized through reconstruction. Another reason could be that the players—particularly the nonoperative group—had functionally stable knees, despite having an increased AP laxity initially. This finding has been reported by Snyder-Mackler et al.[40] in a study of anterior displacement in two groups of nonoperatively treated ACL patients. One of the groups returned to high-level sports activity; the other was not able to continue sport. The authors found no differences in anterior displacement between the groups. They concluded that there was no correlation between AP instability and function.[40] Anteroposterior laxity is not a good test for functional stability because it does not take into ac-

count muscle strength and neuromuscular ability, and knee laxity tests should be dynamic rather than static.[44]

Knee Function

Whether the players were treated operatively or nonoperatively, we found reduced performance in the functional tests and reduced muscle strength in the involved leg compared with the uninvolved leg. The side-to-side differences were moderate (3.8% to 10.1%), and the clinical significance and influence on knee function during activities of daily life or sports activity was unknown. Several investigators have reported that reduced muscle strength correlates moderately with functional knee tests.[32,33,46] However, players with reduced hamstring muscle strength could have a reduced ability to stabilize the knee, resulting in an increased reinjury risk.[17,39]

The Lysholm score result was fair or poor in 29% of the patients, whereas 43% of the patients were classified as abnormal or severely abnormal based on the IKDC evaluation scores. The IKDC is a good method for recording a clinical examination at one follow-up, and, although it has limited value when examining clinical changes over time,[33] it showed that almost half of the patients had significant problems with their knee at follow-up.

Radiologic Findings

Studies have shown that an ACL rupture—alone or in combination with meniscal or collateral ligament injury—results in osteoarthritic changes in 60% to 90% of patients 10 to 20 years after the injury.[27,28,38] After nonoperative treatment of ACL injuries there is a high risk of developing osteoarthritis,[22,42] but one study showed a lower rate of osteoarthritis in nonoperatively treated patients 20 years after injury compared with those with reconstructed knees.[29] Another study reported osteoarthritis in only 1% of patients who had undergone ACL reconstructions 5 to 9 years before.[23] In our study, approximately half of the players for whom radiographs were obtained had developed radiologic signs of osteoarthrosis. These results are not surprising when we consider that so many of the players returned to the high loads and pivoting characteristic of team handball. It should be noted that because Rosenberg, skyline, or lateral views were not available, and patellofemoral arthrosis could not be evaluated, our results represented a minimum estimate of the prevalence of radiographic osteoarthrosis.

Because only 50 of the 78 players recruited for the follow-up study underwent radiologic examination, a selection bias may have existed. However, on the basis of the results from the IKDC and Lysholm evaluations, it does not appear that there was a disproportionate recruitment of players with more knee problems. A more reasonable explanation for the lower rate of radiologic examination could be that some players were unable to travel a considerable distance to have radiographs taken.

Implications

Otto et al.[31] recently stated that, once knee stability has been achieved, the next objective is to return patients to their preinjury levels of activity. This statement probably reflects the treatment goal of most surgeons and therapists working with ACL-injured athletes, as well as the expectations of the injured athletes themselves. On the basis of our findings, it seems reasonable to question whether return to high-level pivoting sports really is in the player's interest—if long-term knee health is the primary concern. The results of the present study show that knee function is compromised in about half of the players 6 to 11 years after an ACL injury, whether they had surgery or were treated nonoperatively. We readily acknowledge that we do not know what the outcome would have been if the players in the operatively or nonoperatively treated groups had not returned to team handball. We also do not know whether the disability observed was caused by the initial injury or was a result of reinjury or of the high-load repetitive twisting strain associated with high-level play, but we do know that the reruptures occurred because the players returned to sport. Finally, we do not know whether the patients' surgical procedures were acceptable compared with contemporary standards. Nevertheless, our results indicate that recommendations concerning return to high-level pivoting sports after an ACL injury should be restrictive, if long-term knee function is the primary objective. In the absence of data to the contrary, the safest advice may be to quit top-level pivoting sports after an ACL injury—whether a reconstruction is performed to stabilize the knee or not.

ACKNOWLEDGMENTS

We thank all the patients who participated in this study. We acknowledge the statistical advice of Ingar Holme, PhD. This work was supported by grants from the Norwegian Sports Medicine Foundation and the Norwegian Olympic Committee and Confederation of Sports.

The Oslo Sports Trauma Research Center has been established at the Norwegian University of Sport and Physical Education through generous grants from the Royal Norwegian Ministry of Culture and the Norwegian Olympic Committee (Oslo), Confederation of Sport, Norsk Tipping AS (Hamar), and Pfizer AS (Voslo), Norway.

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